

## Using the CDIO framework to teach research methodology to informatics students

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**ABSTRACT:** The conceive, design, implement, operate (CDIO) framework is an extended concept for project-based learning. In considering research as a project, the focus of the study described here was the implementation of CDIO for a research methodology (RM) class. The research reported in this article involved 126 third-year undergraduate students. Over about 16 weeks, to pass the course the students were to write a research proposal for their informatics final project. The proposal was developed based on the CDIO framework. The results were promising; 95% of students were able to develop their research proposals on time. Thus, CDIO has the potential to provide a final project framework for computer science and informatics students.

### INTRODUCTION

Research is a methodical investigation to advance knowledge [1]. Most higher-education students must undertake some research to gain a degree. Universities offer a specific course, namely research methodology (RM), to prepare students to undertake research. The aim of this course is to enable students to learn about planning, analysing, designing and implementing research.

Teaching research methodology has attracted researchers' attention. Hren et al found that attending an RM class may improve medical students' confidence in doing scientific research [2]. Another finding was that academics should review and replace outdated materials to improve learners' approach to research [3].

Barakket promoted a combination of a traditional method with a student-centred approach in a research methodology class [4]. In another example, Braguglia and Jackson created a sequential course of statistics, research methodology and organisational behaviour to develop research expertise among undergraduates [5].

On the other hand, Onwuegbuzie and Leech integrate quantitative and qualitative research methodologies into one course and teach both simultaneously [6]. The combination of community-based research and project-based learning may significantly stimulate students to practise research as a group [7]. Hence, RM and its teaching are evolving.

The conceive, design, implement, operate (CDIO) method could be used as a framework for teaching RM. It is a broad, hands-on, verified approach for filling the gap between engineering education and practical engineering needs [8]. This project-driven approach has proved remarkably effective when used for informatics subjects, such as programming [9-12], data structures [13] and embedded systems. Informatics research must support these subjects in a way that addresses real-life problems. Consequently, students should acquire RM knowledge to facilitate their research.

In the State University of Malang (UM), Malang, Indonesia, third-year students must take the RM course as a prerequisite for their fourth-year final project. At the end of the semester, each student must lodge a research proposal with the RM lecturer. The lecturer will mark the proposal and decide whether the student passes the course or not.

Over the past few years, most students have finished the RM course with an excellent score. However, hardly any students do their final project based on these proposals. Most believe that creating a research proposal in their third year is simply a formality without any utility. As a result, they create a different proposal in their fourth year. The aim of this article is to explore the implementation of CDIO for RM classes.

## METHOD

The study was conducted in the State University of Malang during one semester. It involved 126 students from three RM classes in the Informatics Department. Each class comprised 42 students on average. The students were each to create a factual research proposal using the CDIO method. In Table 1 are the CDIO steps undertaken during the 16 weeks of teaching.

Table 1: RM course using CDIO.

CDIO stages	Students' activity	Teacher activity	Product	Period
Conceive	Individual literature search Write group's literature reviews	Explain the problem Guide students on reviewing and paraphrasing the literatures	A literature review article	6 weeks
Design	Design research methods	Evaluate the design	A research framework	4 weeks
Implement	Write a research proposal	Supervise the process	A research proposal	4 weeks
Operate	Perform proposal presentation	Justification for the proposal	An agreed research document	2 weeks

### Conceive Stage

At the beginning of the conceive stage (C), the lecturer sets the course objective, viz. the creation of a research proposal. The proposal is a personal task; however, some writing is group work. The lecturer also provides knowledge about research and the final project. This overview lecture includes:

- research definition;
- research objectives;
- research contribution;
- research methods;
- research evaluation.

At the end of the first class, the lecturer divides students into groups of five and gives an initial discussion topic to each group. This is an informatics topic, such as data mining, machine learning, ubiquitous system or information retrieval.

Afterwards, the students explore their topic through literature reviews and group discussion. The minimum number of literature citations is 25 journal and conference articles. The student group writes a literature review paper in the Institute of Electrical and Electronic Engineers (IEEE) style. Each student should cogitate on their research problem based on factual information, such as from the internet, newspapers or field observations.

In the fifth week, students must lodge their review papers with the lecturer, for content and plagiarism checking. The lecturer will make sure that the papers are well-written and have less than a 20% similarity score. If a paper is below standard, the lecturer will send it back for revision. Individual tasks are discussed in the design stage.

### Design Stage

Students design their project during this, the design stage (D). The product of this stage is a personal research framework. It is used as the basis for research and consists of the following methods:

- research;
- data collection;
- data analysis;
- research evaluation.

It must include all procedures performed by the students, while conducting their research.

### Implement Stage

The aim of the implement stage (I) is the creation of a research proposal. The proposal consists of three chapters: introduction, literature review and research method. The first chapter is an introduction and mainly consists of research background, problem identification, research questions and research objectives.

The second chapter covers theoretical background and associated research, which draws on the literature review article from the C stage. The research method presents the research framework. Other compulsory components of the research proposal are title, abstract and references.

## Operate Stage

In the operate stage (O), students present their research proposal to the RM lecturer. Students must also get approval from the informatics programme co-ordinator. The programme co-ordinator will classify a proposal into one of three research groups:

- information technology;
- software engineering;
- smart computing.

The programme co-ordinator will select two supervisors for each proposal. Students must lodge the signed proposal with the RM lecturer to receive their final RM mark. Table 2 shows the grading system used for the RM final mark.

Table 2: RM grading system.

Score range	Grade
85-100	Very Good
75-84	Good
60-74	Fair
50-59	Bad
0-45	Fail

Classroom observations to collect both qualitative and quantitative data formed the research reported in this article. Both the findings of the observations and descriptive statistics were analysed. The reflections reported in this article could be used as a foundation for informatics curriculum development.

## RESULTS AND DISCUSSION

The 16 weeks of RM study based on CDIO were satisfactorily completed. All groups were competent in creating their systematic literature review paper. On average, 31 articles from conference proceedings and journal articles were cited. A reference manager tool, the Mendeley Desktop, assisted writing in the IEEE style. The articles passed the similarity testing with an average score of 17%. Each group member also found a factual problem for their personal research proposal.

Students were proficient in creating a methodical research design. They were able to construct a research proposal based on the integration of their personal ideas, the group literature review and the research design. Most students wrote up and presented their research proposal. The breakdown of students' final marks is shown in Figure 1.

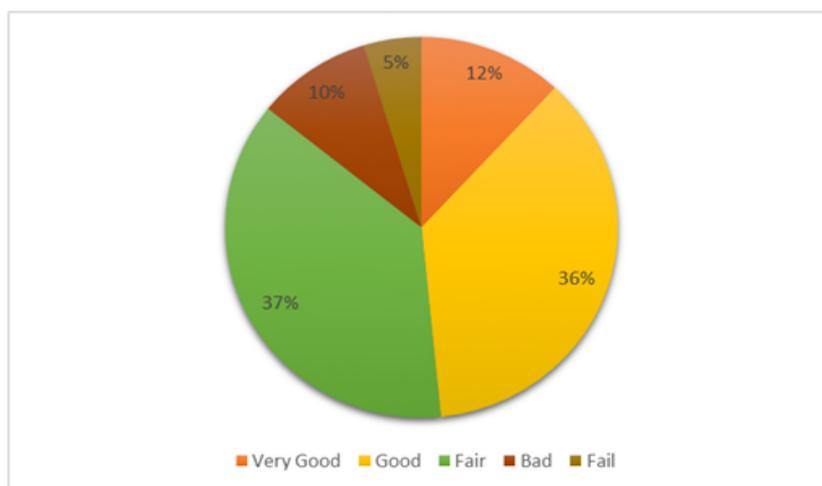


Figure 1: Students' final marks.

Twelve students passed the course with a minimum grade of *bad* (10%). Five percent of students failed and had to retake the RM class the following year. Since the great majority (85%) had results from *very good* to *fair*, the course is considered effective in directing students to create research proposals.

Table 3 presents the statistics in more detail. However, having a good score does not mean there were no problems. During the CDIO stages, students encountered several problems related to the research topic diversity, language proficiency or lack of familiarity with the CDIO framework.

Table 3: Frequency distribution of RM classes.

Score range	Grade	Class-A	Class-B	Class-C	Total
85-100	Very good	3	10	2	15
75-84	Good	23	11	12	46
60-74	Fair	12	15	20	47
50-59	Bad	3	5	4	12
0-45	Fail	1	3	2	6
Number of students		42	44	40	146
Average score		70.23	67.3	66.79	68.13
Standard deviation		13.22	18.23	13.07	15.06

### Problem of Understanding the CDIO Framework

The first problem was associated with students' understanding of the CDIO framework. At every stage, there were problems to tackle. For instance, at the beginning of C stage, most students were confused since the lecturer asked them to work in a group to create a literature review and, on the other hand, to discover their individual research topic.

The lecturer needs to describe the significance of collaboration in finishing the project. This initial vagueness gradually vanished as students grasped the essence of the CDIO concept. In a team-based environment, students should be able to conceive-design-implement-operate complicated modern systems and technologies [14]. Table 4 presents the problems encountered and solutions to the problems during the CDIO stages.

Table 4: Problems and solutions during CDIO stages.

No.	Stage	Students' question/problem	Teacher's answer/action
1a	Conceive	<ul style="list-style-type: none"> <li>Students must co-operate to construct their personal research proposal</li> </ul>	<ul style="list-style-type: none"> <li>The core of CDIO is collaboration, which may ease and speed up the proposal creation.</li> </ul>
1b	Conceive	<ul style="list-style-type: none"> <li>The group literature review does not match the discovered personal problem</li> </ul>	<ul style="list-style-type: none"> <li>Ask students to use other groups' literature review with proportional adjustment to avoid plagiarism.</li> <li>Ask students to consult with a specific lecturer or expert related to their research topic.</li> <li>Ask some students to do the lecturers' project to ease the discovery process.</li> </ul>
2	Design	<ul style="list-style-type: none"> <li>Form a research design based on the discovered problem and literature reviews</li> </ul>	<ul style="list-style-type: none"> <li>Select a case as an example.</li> <li>Ask students to do peer-reviews for design validation and quality assurance.</li> </ul>
3	Implement	<ul style="list-style-type: none"> <li>How to construct a good research proposal</li> </ul>	<ul style="list-style-type: none"> <li>Give an example.</li> <li>Ask students to write their first draft individually.</li> <li>Ask the group to criticise the draft for improvement.</li> </ul>
4	Operate	<ul style="list-style-type: none"> <li>No experience in research proposal presentation</li> </ul>	<ul style="list-style-type: none"> <li>Explain the process and give an example.</li> <li>Ask students to practise in a group.</li> </ul>

### Topic Diversity and Linguistic Challenges

Another problem was topic diversity. Even though the lecturer asked students to create literature reviews of various popular IT topics, most had a tendency to select data mining, machine learning and information retrieval for their proposal topic. These were elective topics held at the same time as RM. Furthermore, other advanced topics, such as grid computing and ubiquitous system were taught in the next semester. Students may believe that carrying out research with inadequate background knowledge would be ineffective [1].

Some students faced linguistic difficulties. Students had to write in formal *Bahasa Indonesia*, the official language of Indonesia, while most of the literature was in English. Students struggled to understand English, which is not their mother tongue. Another problem was writing in the formal Indonesian language. Students tended to write awkward sentences with illogical paragraph design. The sentence awkwardness may prevent the readers' understanding due to the use of incorrect expressions, repetition and sentences that were too long. Furthermore, paragraphs may be inconsistent with several unconnected ideas.

## Addressing the Difficulties Experienced on the RM Course

The difficulties experienced on the RM course should be addressed to improve the students' performance. A possible solution is to restructure the curriculum, so that CDIO is implemented in every informatics major [15]. As a result, CDIO would be more widely implemented in the academic environment. Furthermore, the RM course could be moved to the seventh semester since this is where all advanced courses are delivered.

In terms of linguistic problems, the English course should have more emphasis on English-Indonesian translation. Also, the Indonesian language course should be more focused on academic writing. If all these steps were taken, the students would have a better experience on the CDIO-based RM course.

## CONCLUSIONS

Some engineering research should be undertaken by students before they become engineers [14]. The results should demonstrate the students' technology-based knowledge, skills and attitude. However, undergraduate engineering research at university tends to focus on the theoretical foundations of a particular discipline rather than its application or synthesis [14].

The authors implemented the CDIO framework to fill this gap. Embedding CDIO into a research methodology course produced positive results as revealed by students' performance in creating a research proposal. To further improve performance, students should develop their language proficiency and use CDIO more frequently.

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